SEISMIC DESIGN FOR REINFORCED CONCRETE OFFICE BUILDING INFLUENCED BY CONCRETE GRADE AND LEVEL OF SEISMICITY

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University of Malaysia Pahang or any other institutions.

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ABSTRAK

Gempa bumi adalah bencana alam yang boleh mengakibatkan runtuh bangunan. Bangunan pejabat adalah tempat pekerja melakukan kerja mereka, apabila gempa berlaku, bangunan itu tidak akan mampu menahan gempa bumi yang mungkin berbahaya kepada orang. Oleh itu, untuk menjadi tempat yang selamat, bangunan itu mesti menahan bencana seperti gempa bumi. Malaysia dianggap mempunyai profil seismicity yang rendah tetapi lebih banyak bukti menunjukkan bahawa anggapan awal Malaysia bebas daripada gempa bumi yang mengelirukan. Gempa bumi pada tahun 2004 gempa bumi India-India dengan magnitud 9.1 yang membunuh 68 nyawa di Malaysia dan beribu-ribu orang lain di Indonesia, Sri Lanka dan Thailand. Oleh itu, kerja-kerja ini akan memberi tumpuan kepada mengkaji kesan reka bentuk seismik terhadap berat pengukuhan keluli dan jumlah konkrit yang digunakan untuk bangunan pejabat. Objektif pertama ialah mengkaji kesan pada magnitud PGA pada jumlah pengukuhan keluli. Objektif kedua ialah mengkaji kesan pada gred konkrit pada jumlah pengukuhan keluli. Dan objektif ketiga untuk kajian ini adalah untuk mengkaji pengaruh PGA dan gred konkrit pada anggaran kos. Dalam keseluruhan 16 model bangunan pejabat konkrit bertetulang dengan bilangan 3 dan 6 tingkat akan digunakan dalam analisis ini. Model-model ini akan direka bentuk untuk dua gred konkrit yang berbeza iaitu G25 dan G30. Nilai PGA akan ditetapkan sebagai 0.03g, 0.09g dan 0.15g. Kajian ini hanya menilai medium dan jenis tanah kelas kemuluran D. Perisian struktur Tekla akan digunakan untuk analisis dan direka berdasarkan Eurocode 8 (2004). Perbandingan akan dibuat dari segi jumlah keluli yang diperlukan sebagai 1m3 konkrit bagi setiap model. Untuk magnitud PGA yang berbeza, hasilnya menunjukkan bahawa perbezaan peratusan pengukuhan keluli yang diperlukan untuk model bukan seismik bangunan 3 tingkat dan 6 tingkat telah meningkat dari 2%, 14% dan 56% dan 7%, 49% dan 162% bagi pecutan puncak puncak rujukan, agR = 0.03g, 0.09g dan 0.15g masing-masing. Walaupun untuk nilai gred konkrit yang berlainan, hasilnya menunjukkan bahawa perbezaan peratusan pengukuhan keluli yang diperlukan untuk model bukan seismik bangunan 3 tingkat dan 6 tingkat telah berkurang dari 36% kepada 56% dan 162% kepada 139% mengikut gred konkrit yang berlainan. Oleh itu, magnitud PGA dan gred konkrit struktur memberikan kesan yang signifikan kepada jumlah keseluruhan pengukuhan keluli yang diperlukan. Oleh itu, ia perlu dipertimbangkan dalam merekabentuk bangunan seismik.

ABSTRACT

Earthquake is a natural disaster that may lead to collapsing of building. Office building is a place the employee do their work, when earthquake happened, the building will not be able to withstand the earthquake which may be dangerous to people. So, in order to be a safe place, the building must withstand the disaster such as earthquake. Malaysia is considered to have a low seismicity profile but more evidences are showing that early assumption Malaysia is free from earthquake are misleading. The earthquake on 2004 Indian-Ocean earthquake with magnitude 9.1 which killed 68 lives in Malaysia and thousands others in Indonesia, Sri Lanka and Thailand. Therefore, this work will focus on study the effect of seismic design on the weight of steel reinforcement and volume of concrete used for office building. The first objectives is to study the effect on magnitude of PGA on the amount of steel reinforcement. The second objectives is to study the effect on grade of concrete on the amount of steel reinforcement. And the third objectives for this research is to study the influence of PGA and grade of concrete on cost estimation. In the total of 16 models of reinforced concrete office building with number of 3 and 6 storeys will be used in this analysis. The models will be design for two different grade of concrete which are G25 and G30. The value of PGA will be fixed as 0.03g, 0.09g and 0.15g. This study only considered the ductility class medium and soil type D. Tekla structure software will be used for analysis and designed based on Eurocode 8 (2004). The comparison will be made in term of amount of steel required as $1m^3$ of concrete for every model. For different magnitude of PGA, the result shows that the percentage difference of steel reinforcement required to non-seismic model of 3-storey and 6-storey office building had increased from 2%, 14% and 56% and 7%, 49% and 162% for reference peak ground acceleration, agR = 0.03g, 0.09g and 0.15g respectively. While for different value of grade of concrete, the result shows that the percentage difference of steel reinforcement required to non-seismic model of 3-storey and 6-storey office building had decrease from 36% to 56% and 162% to 139% respectively according to different grade of concrete. Thus, magnitude of PGA and concrete grade of structure give significant effect to overall amount of steel reinforcement required. Hence, it should be considered in designing a seismic building.

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LIST OF SYMBOLS

ag	Design ground acceleration
a_{gR}	Reference peak ground acceleration
Asprov	Total area of steel provided
Asreq	Total area of steel required
dbL	Diameter of longitudinal bar
d_{bw}	Diameter of shear or confinement bar
F_b	Base shear force
fcd	Design value of concrete compressive strength
f*ck*	Characteristic cylinder strength of concrete
*F*i	Lateral load on storey
*F*y	Yield strength of reinforcement
g	Acceleration due to gravity, m/s2
*G*k	Dead load
H	Storey height
M	Bending moment
m	mass of structure
*M*Rb	Design moment resistance of beam
*M*Rc	Design moment resistance of column
Mw	Magnitude of earthquake intensity
q	Behaviour factor
*Q*k	Live load
S	Soil factor
Sd(T1)	Ordinate of the design spectrum at period
*T*1	Fundamental period of vibration
*T*B	Lower limit of the period of the constant spectral acceleration
*T*C	Lower limit of the period of the constant spectral acceleration
*T*D	Beginning of the constant displacement response range of the spectrum
V	Beginning of the constant displacement response range of the spectrum

LIST OF ABBREVIATIONS

DCH	Ductility class high
DCL	Ductility class low
DCM	Ductility class medium
Kelastic	Elastic stiffness
PGA	Peak ground acceleration
RC	Reinforced Concrete

CHAPTER 1

INTRODUCTION

1.1 Introduction

Earthquake is a natural disaster that shows a results of shifting plates in the crust of earth and resulting a sudden release of energy in the earth of lithosphere which creates seismic waves. Earthquake happens when the earth plate move with respect to one another which make stress build up due to friction and stored. After that, it releases in the form of seismic waves which induce ground shaking. The shaking and the ground rupture are the main effects that created by earthquakes which can bring damage to building and rigid structures. According to (Martín-gonzález, 2018) damage in architectonic elements of buildings as shown in Figure 1.1 are one of the effects observed after earthquakes, and they can remain in historical buildings and archaeological sites for years and even centuries as a witness of the earthquake. Such earthquake damage can be used to complete historical seismic catalogue and give information about earth- quake parameters.

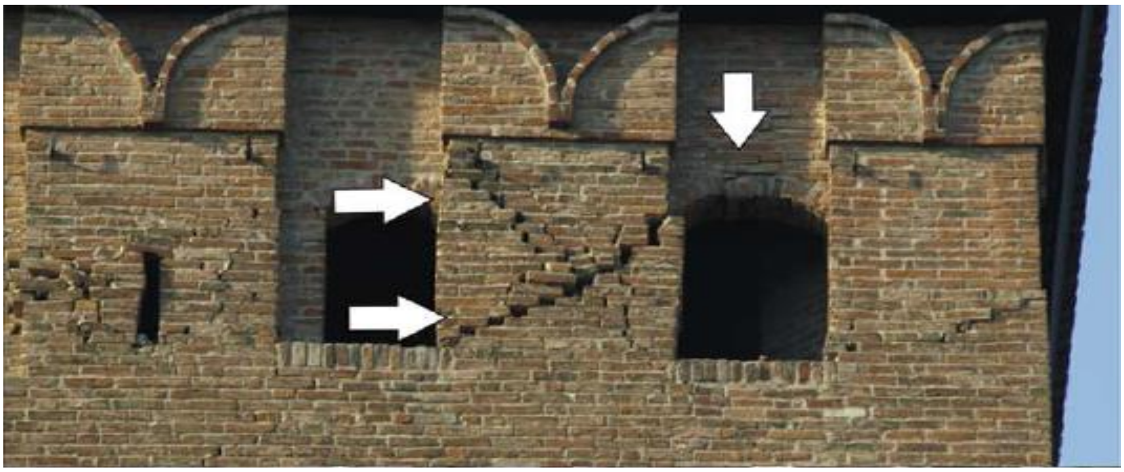

Figure 1.1: Conjugated fracture sets and dropped keystones in windows

Most earthquakes occur along the edge of the oceanic and continental plates. The earth's crust is made up of several pieces, called plates. The plates under the oceans are called oceanic plates and the rest are continental plates. The plates are moved around by the motion of a deeper part of the earth (the mantle) that lies underneath the crust. These plates are always bumping into each other, pulling away from each other, or past each other. The plates usually move at about the same speed that your fingernails grow. Earthquakes usually occur where two plates are running into each other or sliding past each other. Earthquakes can also occur far from the edges of plates, along faults. Faults are cracks in the earth where sections of a plate (or two plates) are moving in different directions. Faults are caused by all that bumping and sliding the plates do. Figure 1.2 shows the different types of faults which is normal, reverse and strike-slip.

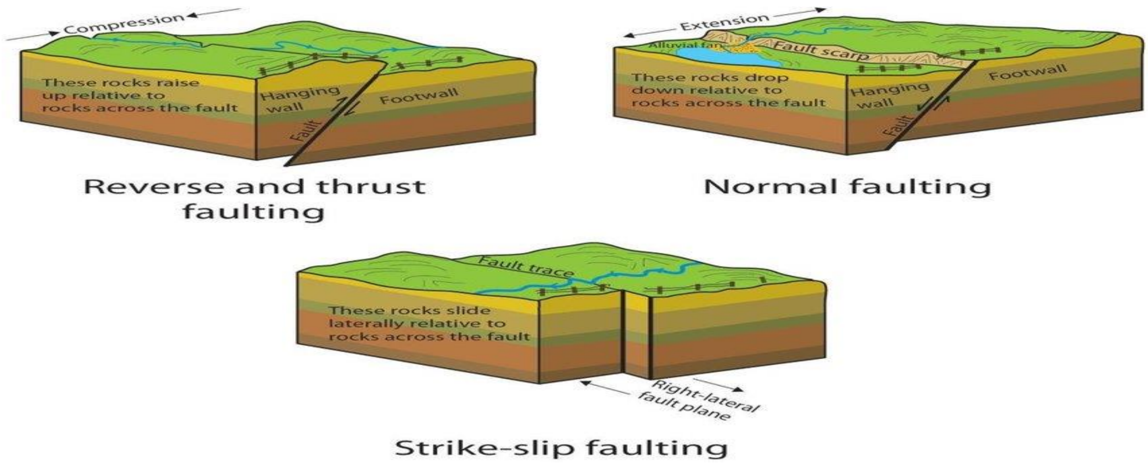

Figure 1.2: Types of faults (Normal, Reverse and Strike-Slip)

Malaysia is considered to have a low seismicity profile but more evidences are showing that early assumption Malaysia is free from earthquake are misleading. This is because, as the previous recorded earthquake that occurred in the neighboured countries such as Thailand and Indonesia, Malaysia is occasionally subjected to tremors. In accordance to the geological map of Peninsular Malaysia published by the Mineral and Geoscience Department of Malaysia (JMG), three prominent set of fault systems trending in N-S, E-W, and NW-SE directions were recognized. Seven major faults with strike-slip mechanism were listed within the region, including Bukit Tinggi fault, Kuala Lumpur fault, Bok Bak fault, Lebir fault, Terengganu fault, Lepar fault, and Mersing fault (Minerals and Geoscience Department Malaysia, 2014). The boundaries have been formed by the Hulu Kelang-Kongkoi fault zone and the Bukit Tinggi fault zone as shown in Figure 1.3.

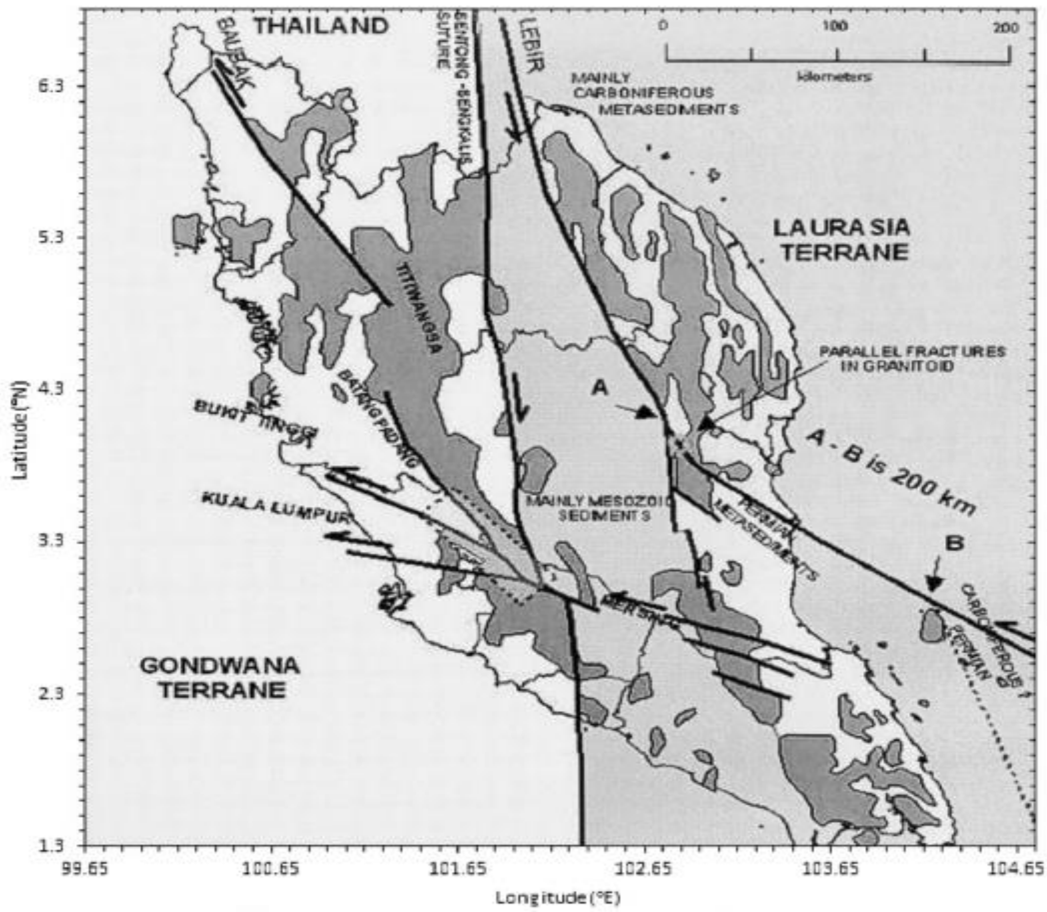

Figure 1.3: Local tectonic framework of Peninsular Malaysia (Minerals and Geoscience Department Malaysia, 2012).

1.2 Problem Statement

Earthquake had happened in Malaysia and also worldwide even though it is small or large magnitude. However, Malaysia has lack awareness about earthquake. Malaysia had experienced several local tremors from earthquakes which was occurred in Sabah, Peninsular Malaysia and also far field earthquakes from Indonesia and Philippine. In June 2015, Ranau was struck by a 6.0-magnitude earthquake. There were 18 people, including 9 Singaporeans, were killed when they were struck by falling rocks on Mount Kinabalu and also some 137 climbers were stranded on the mountain but were later rescued. Through the incidents, people starts to questioning that the building in Malaysia is strong enough to withstand or the resist earthquake.

REFERENCES

Irwansyah, E., Winarko, E., Rasjid, Z. E., & Bekti, R. D. (2013). Earthquake hazard zonation using peak ground acceleration (PGA) approach. *Journal of Physics: Conference Series*, *423*(1). https://doi.org/10.1088/1742-6596/423/1/012067

Adiyanto, M. I., & Majid, T. A. (2014). Seismic design of two storey reinforced concrete building in Malaysia with low class ductility. *Journal of Engineering Science and Technology*, 9(1), 27–46.

Adiyanto, M. I., (2016). Influence of Behaviour Factor on Seismic Design and Performance of Reinforced Concrete Moment Resisting Frame in Malaysia, Univeriti Sains Malaysia pp 1-240.

Adiyanto M.I et al (2019), Estimation on amount of steel reinforcement for six storey hospital building with seismic design consideration in Malaysia, *Earth and Environmental Science* 244 (2019) 012015, 5-6

Judd, J. P., & Pakwan, N. (2018). Seismic performance of steel moment frame office buildings with square concrete-filled steel tube gravity columns. *Journal of Engineering Science and Technology*, 27-46

Martín-gonzález, F. (2018). Tectonophysics Earthquake damage orientation to infer seismic parameters in archaeological sites and historical earthquakes, 725(December 2017), 137–145.

Ahmad Jani (2018), Seismic Design For Reinforced Concrete Hospital Building Influenced By Level Of Peak Ground Acceleration And Class Of Ductility *Universiti Malaysia Pahang Thesis.* p 34-49

Yaakup (2018), Influence Of Concrete Grade And Level Of Seismicity On Seismic Design Of Reinforced Concrete School Building *B . Universiti Malaysia Pahang Thesis* p 32-46

Saka (2018), Effect of Soil Type and Grade of Concrete on Amount of Steel for Reinforced Concrete Hospital Building With Seismic Design *Universiti Malaysia Pahang Thesis* p 46-63

Jabatan Kerja Raya, Schedule of Rates for The Supply of All Labour, materials, tools, plants, appliances and everything else necessary for the erection and completion (2017)

Ramli M Z, Adnan A, Kadir M A A and Alel M N A 2017 Cost comparison for non-seismic (EC@) and seismic (EC8) design in different ductility class *International Journal of Civil Engineering & Geo-Environmental*. **Special Publication NCWE2017** 38

Eurocode 8: Design of Structures For Earthquake Resistance, Part 1: General Rules, Seismic Actions And Rules For Buildings (2004), *The British Standards Institution.*

Eurocode 1: Actions on Structures, Part 1-1: General Actions, Densities, Self-weight, Imposed Loads for Buildings (2002), *The British Standards Institution*

Mantawy A. (2018), Effect of long-duration earthquakes on the low-cycle fatigue damage in RC frame buildings, *Soil Dynamic and Earthquake Engineering*, Volume 109, June 2018, Pages 46-57, https://doi.org/10.1016/j.soildyn.2018.01.013

Li et al., (2019), Optimum seismic design of multi-story buildings for increasing collapse resistant capacity, *Soil Dynamics and Earthquake Engineering* 116 (2019) 495–510, www.elsevier.com/locate/soildyn

McKenzie, W. M. C. (2004). Design of Structural Elements, 656. New York, Palgrave Macmillan pp.616.

MOSTI, (2009), Malaysian Meteorological Service. Seismic and Tsunami Hazards and Risks Study in Malaysia.

MOSTI, (2017), Malaysian Standards (MS) for earthquake-resistant buildings design code. *Technology and Innovation (Mosti), Department of Standards Malaysia*, https://www.thesundaily.my/archive/mosti-develops-standards-earthquake-resistant-structural-designs-HUARCH508331

Mineral and Geoscience Department Malaysia, (JMG), (2012), Geological map of peninsular Malaysia